

Global Isoprene Emissions Constrained by OMI Formaldehyde Column Measurements

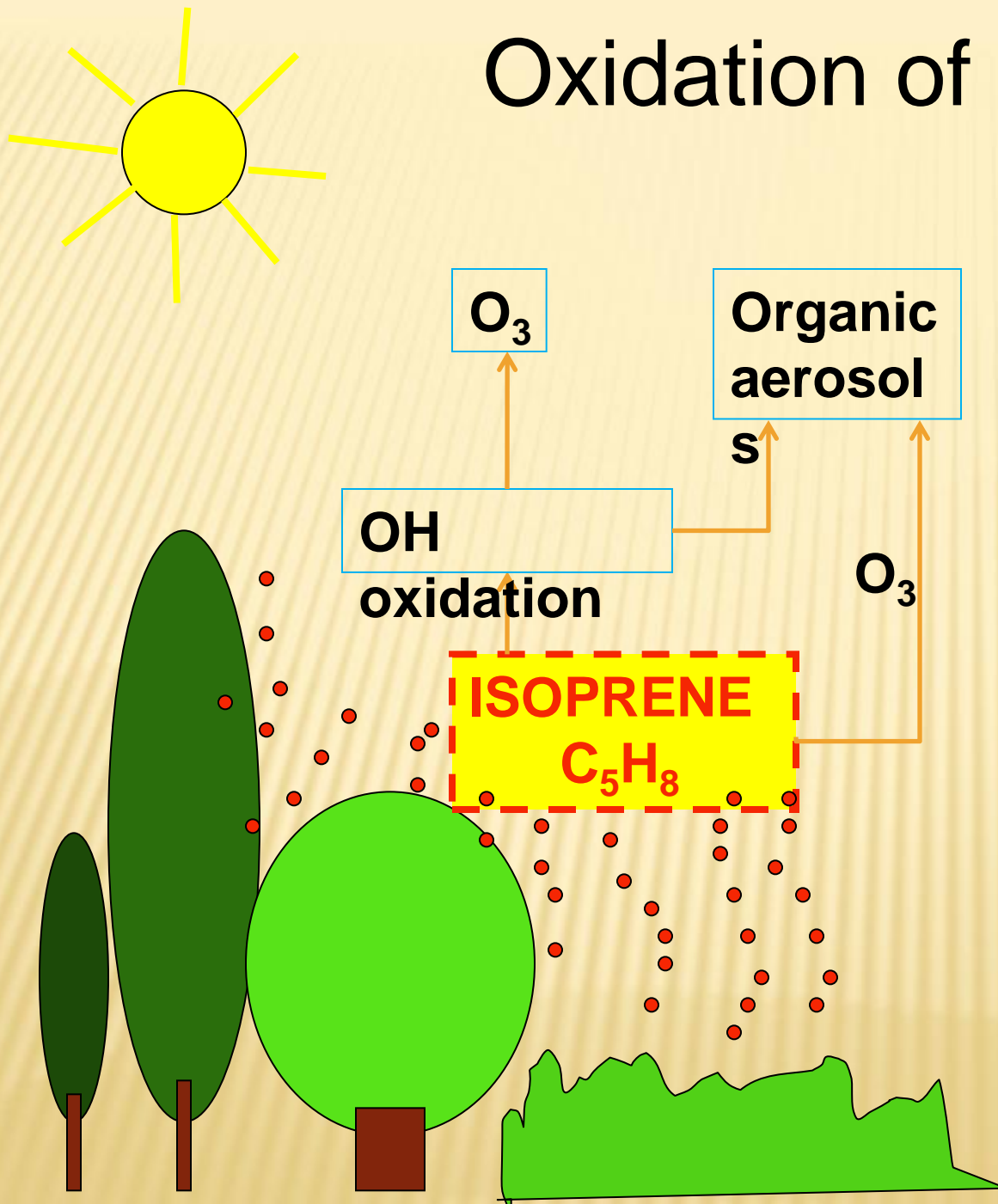
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Oxidation of Isoprene



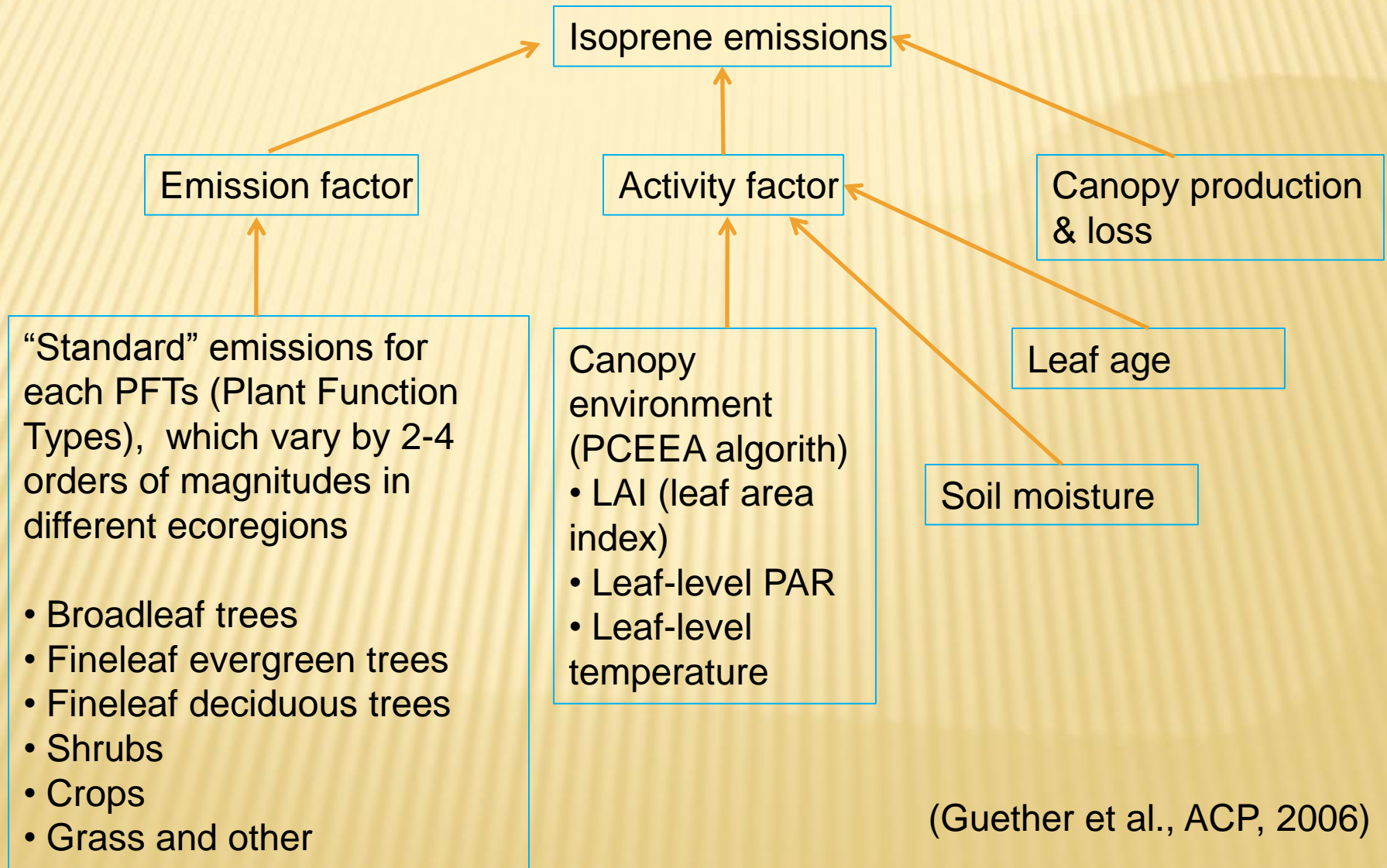
Most dominant biogenic hydrocarbon

Isoprene global budget is highly uncertain.

Emissions depend on:

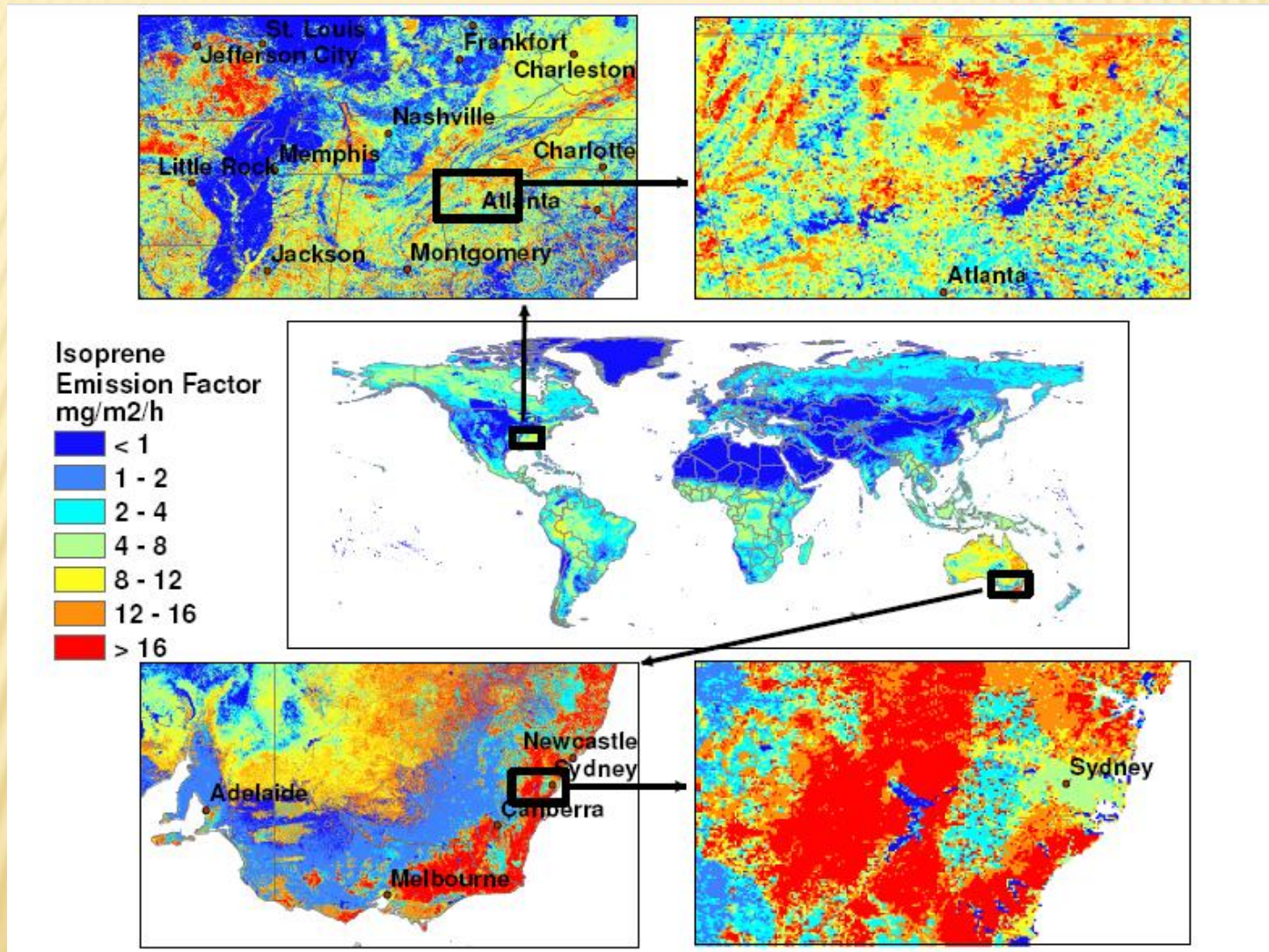
- Vegetation type
- Leaf area index
- Light intensity
- Temperature
- Soil moisture

MEGAN Isoprene Emission Inventory



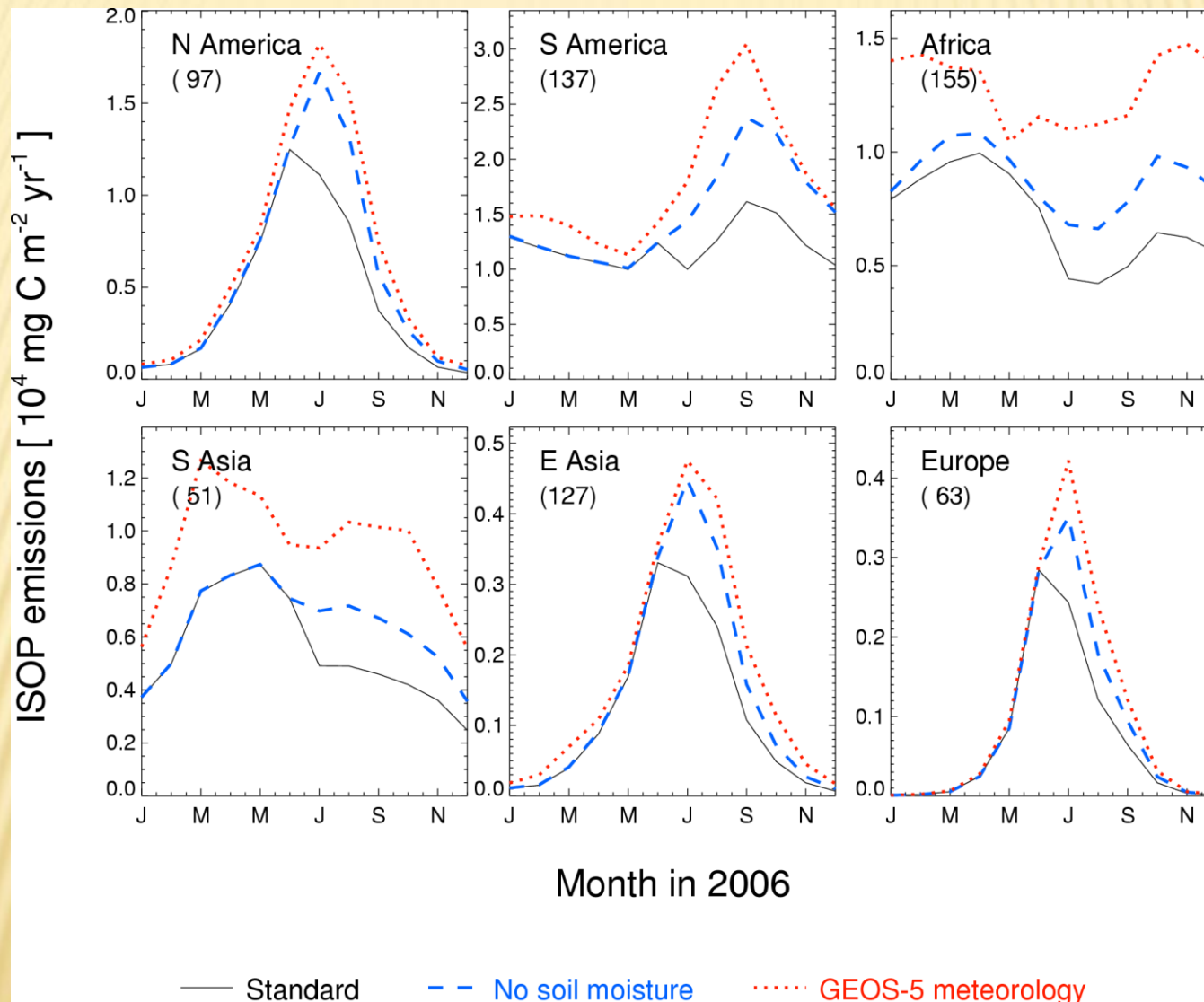
(Guether et al., ACP, 2006)

Uncertainty: Spatial variability



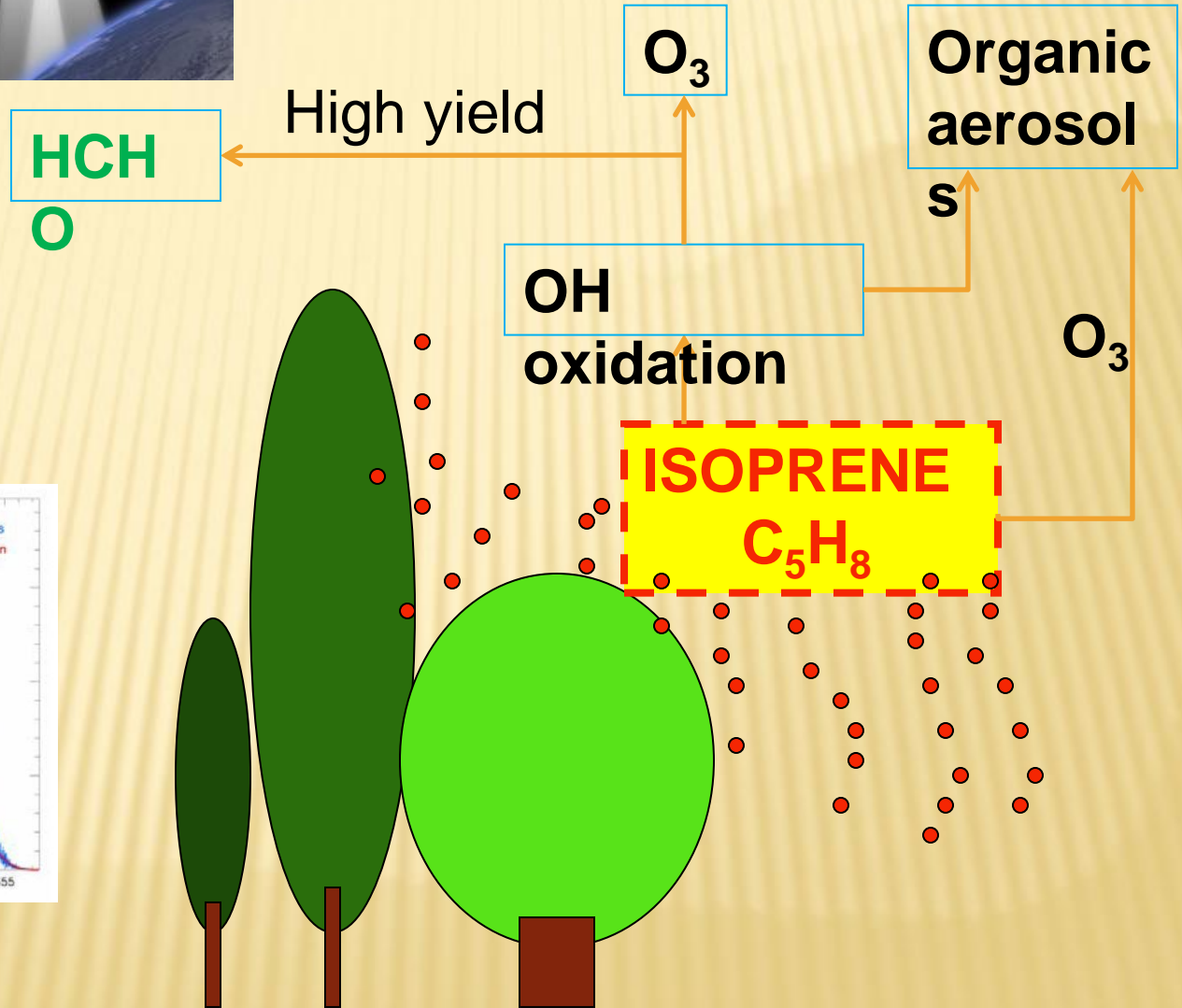
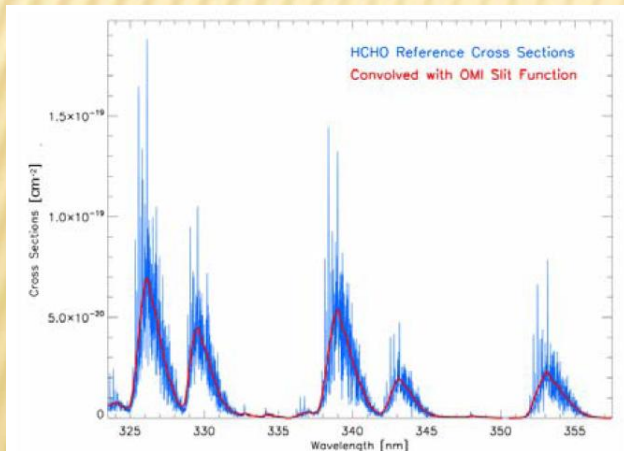
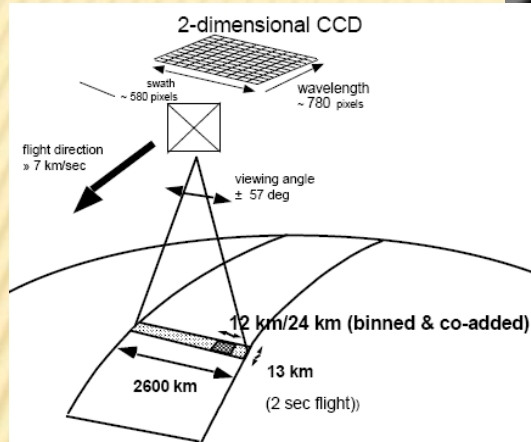
(Guether et al., 2006)

Effect of soil moisture

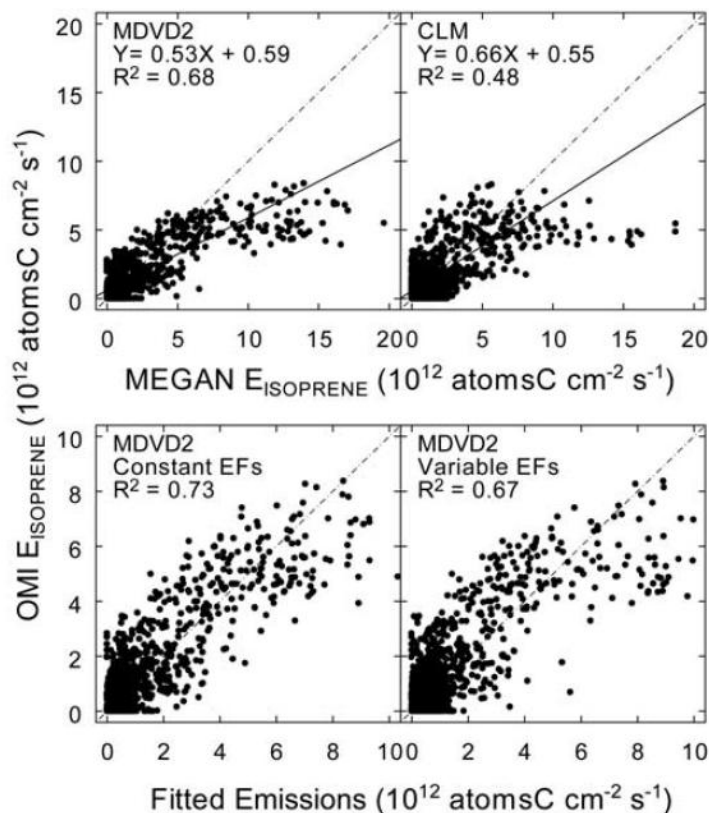
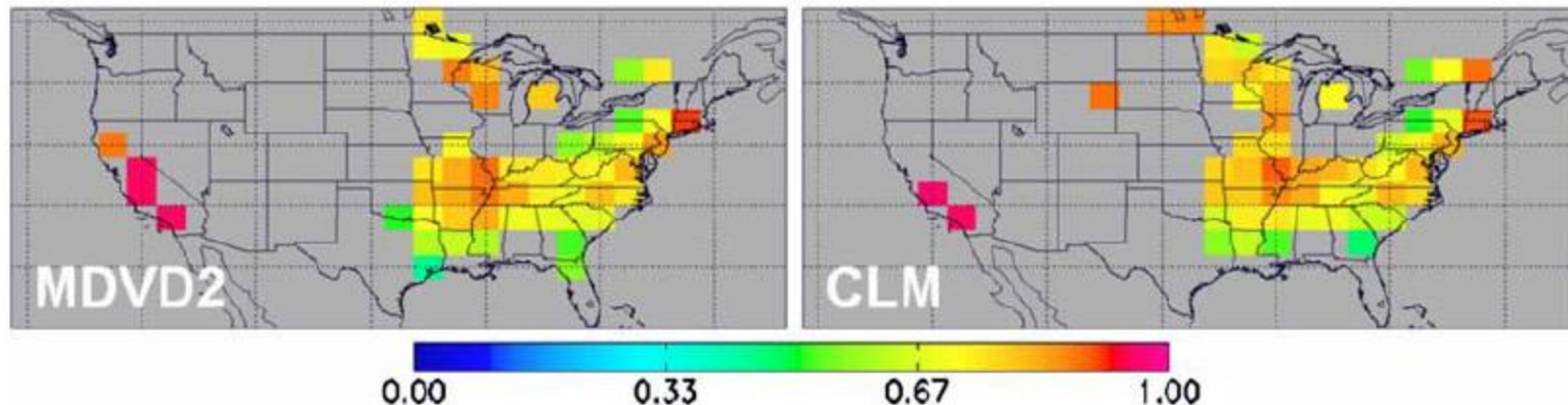


Global isoprene emissions are reduced by 22% in 2006

OMI HCHO



Correlation Coefficient



- GEOS-Chem OMI HCHO column in summer, 2006 compared to OMI
- OMI HCHO columns are 4-25% lower than model results depending on the PFT distributions
- The model high bias is large when estimated emissions are higher than 7×10^{12} atoms C cm^{-2} s^{-1} .

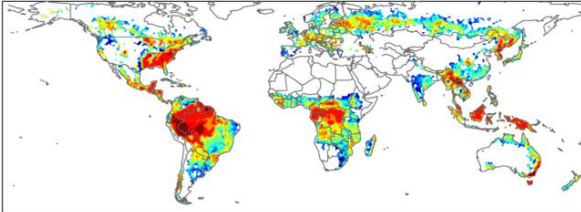
(Millet et al., JGR, 2008)

Inversion of global isoprene emissions

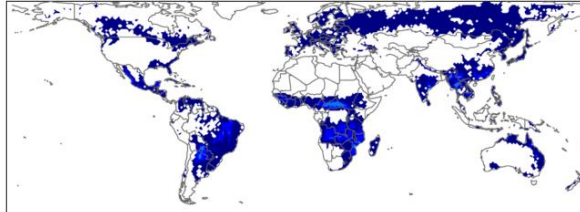
- ✗ OMI HCHO measurements and GEOS-Chem simulations in 2006
- ✗ Bayesian inversion: source specific and explicit a posteriori uncertainty estimates
 - + Broadleaf
 - + Shrubs
 - + Other biogenic emissions
 - + Biomass burning
 - + Fossil sources

Isoprene emission factor distributions

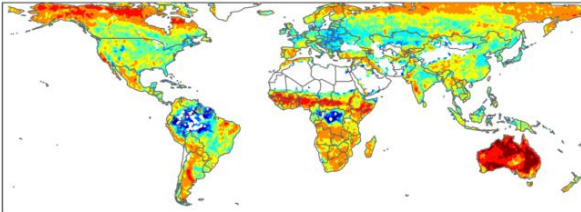
Broadleaf trees



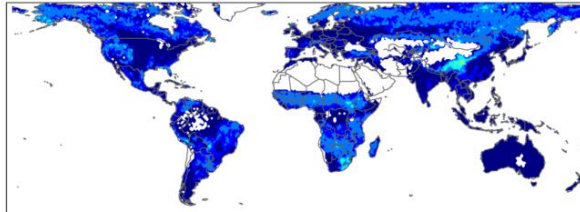
Fineleaf deciduous trees



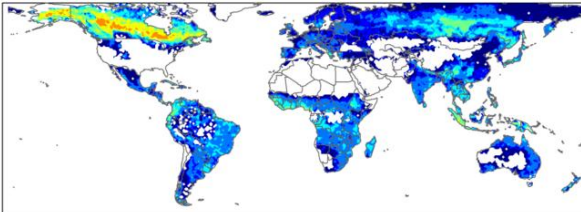
Shrubs



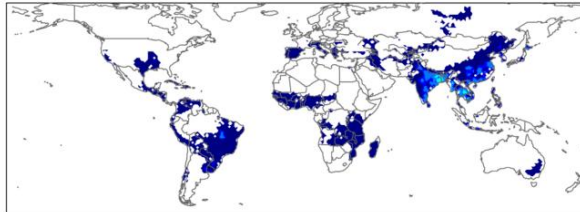
Grass and other



Fineleaf evergreen trees



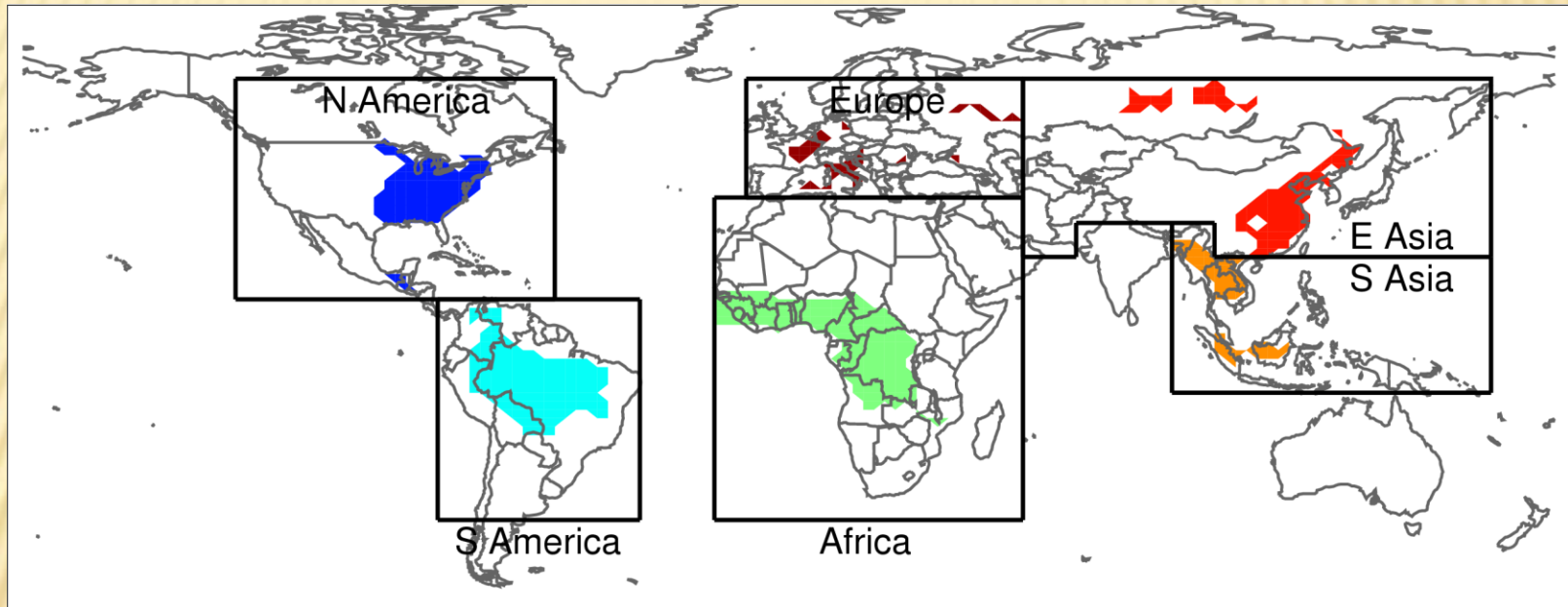
Crops



Isoprene emission factor [$\text{mg m}^{-2} \text{h}^{-1}$]



Inversion regions



- PFT emission factors vary by region due to the diversity of ecosystems
- Signal to noise ratio > 4

Inversion: Bayes' Theorem

$P(\mathbf{x})$ = probability distribution function (pdf) of \mathbf{x}

$P(\mathbf{y}|\mathbf{x})$ = pdf of \mathbf{y} given \mathbf{x}

$$\underbrace{P(\mathbf{x}|\mathbf{y})}_{\text{A posteriori pdf}} = \frac{\underbrace{P(\mathbf{y}|\mathbf{x})}_{\text{Observation pdf}} \underbrace{P(\mathbf{x})}_{\text{A priori pdf}}}{\underbrace{P(\mathbf{y})}_{\text{Normalizing factor}}}$$

Maximum *a posteriori* (MAP) is the solution to $\nabla_{\mathbf{x}} P(\mathbf{x} | \mathbf{y}) = \mathbf{0}$

Bayesian Inversion

$$\mathbf{y} = \mathbf{K}\mathbf{x} + \mathbf{e}$$

\mathbf{y} : Observations (OMI HCHO)

\mathbf{x} : Isoprene source parameters (GEOS-Chem)

\mathbf{K} : Jacobian matrix (sensitivity of \mathbf{x} to \mathbf{y} , GEOS-Chem)

\mathbf{e} : error term

Forward model: GEOS-CHEM

The solution:

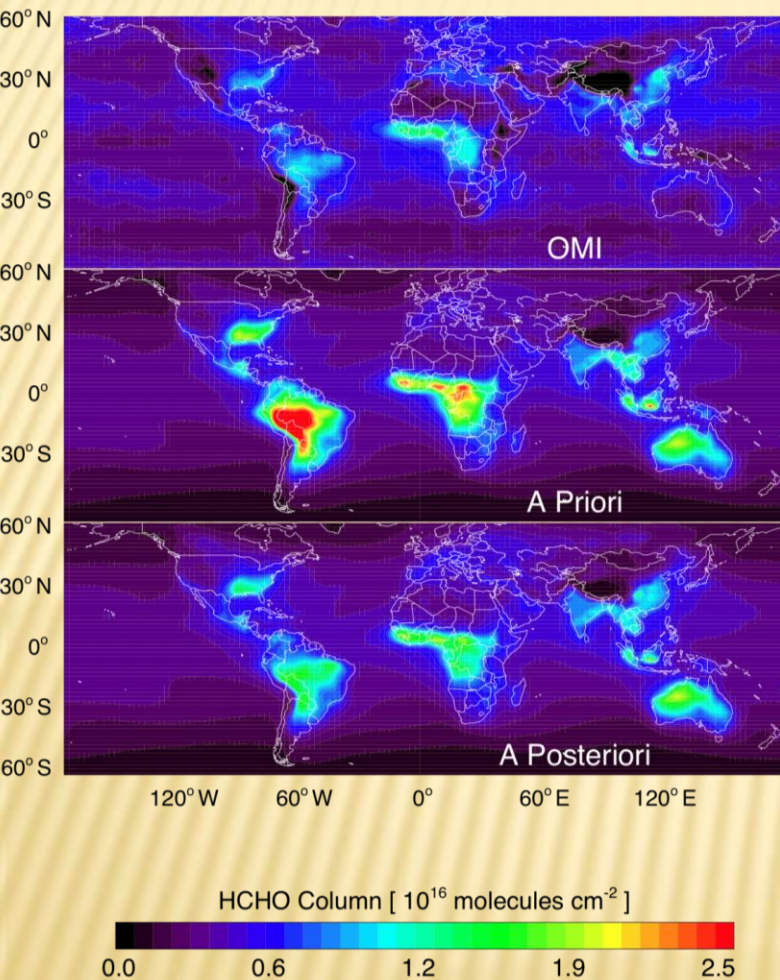
$$\hat{\mathbf{x}} = \mathbf{x}_a + (\mathbf{K}^T \mathbf{S}_e^{-1} \mathbf{K} + \mathbf{S}_a^{-1})^{-1} \mathbf{K}^T \mathbf{S}_e^{-1} (\mathbf{y} - \mathbf{K} \mathbf{x}_a),$$

$$\hat{\mathbf{S}} = (\mathbf{K}^T \mathbf{S}_\varepsilon^{-1} \mathbf{K} + \mathbf{S}_a^{-1})^{-1}$$

$$= \mathbf{S}_a - \mathbf{S}_a \mathbf{K}^T (\mathbf{K} \mathbf{S}_a \mathbf{K}^T + \mathbf{S}_\varepsilon)^{-1} \mathbf{K} \mathbf{S}_a$$

(Roger, 2000)

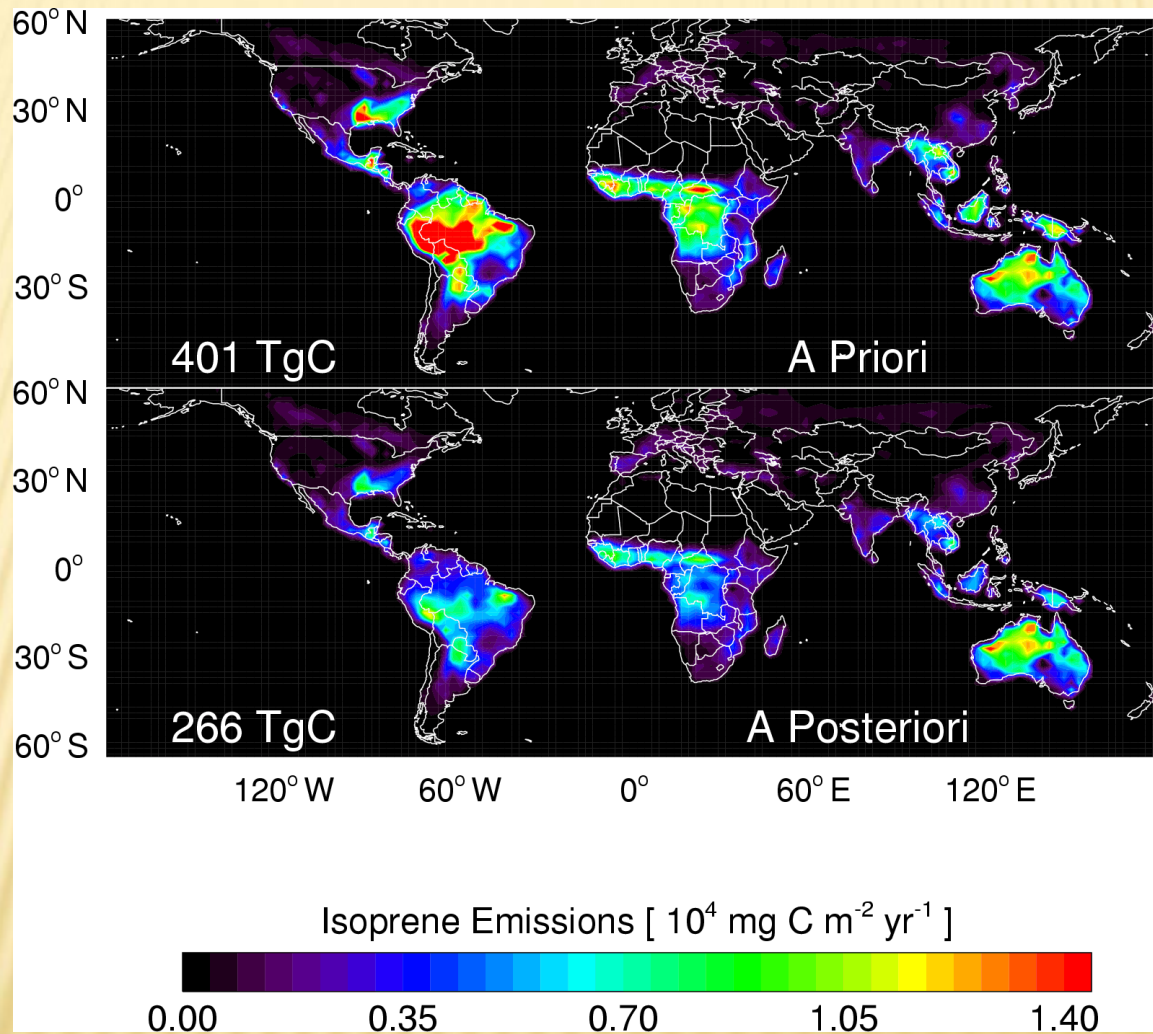
Bayesian Inversion: HCHO columns



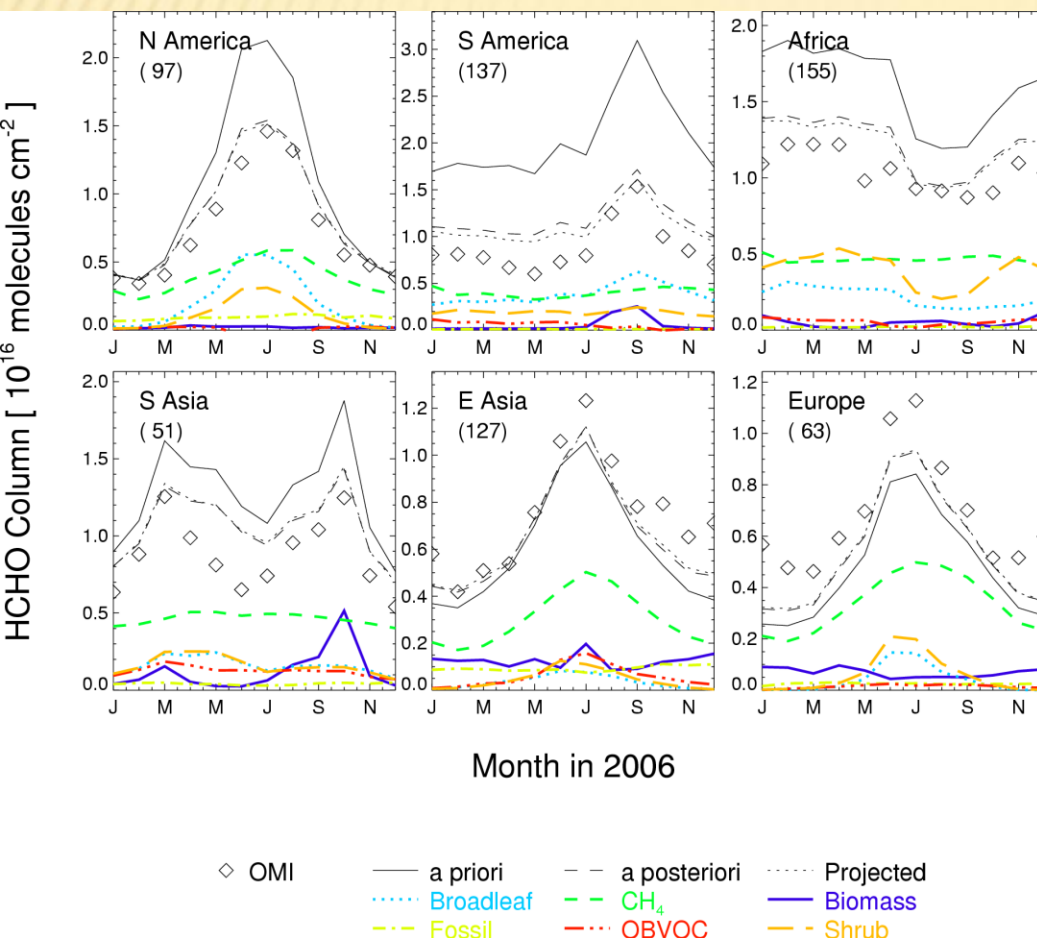
Region	Isoprene emissions		Weighted uncertainty ^c	
	Tg C/yr		%	
	pri	post	pri	post
N. America	38.9	25.5	369	135
S. America	146	69.5	350	53
Africa	98.2	66.5	376	67
South Asia	35.4	22.6	374	95
East Asia	15.3	13.1	369	118
Europe	7.3	9.6	377	162
Global	401	266		

- Significant reduction over regions with large biogenic emission: N. America, S. America, Africa, South Asia (excluding India)
- Uncertainties are reduced but remain large

Bayesian Inversion: Emissions



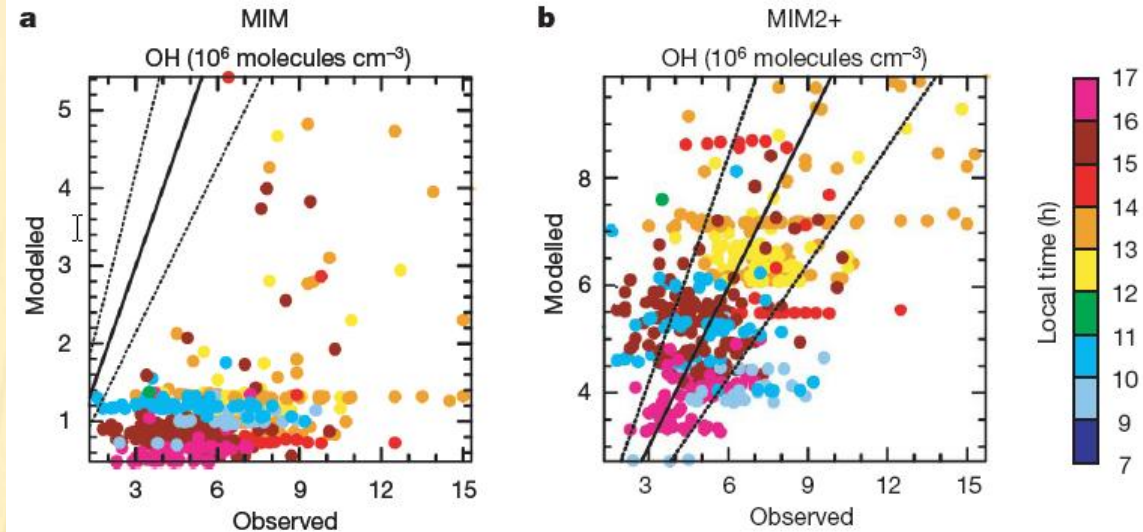
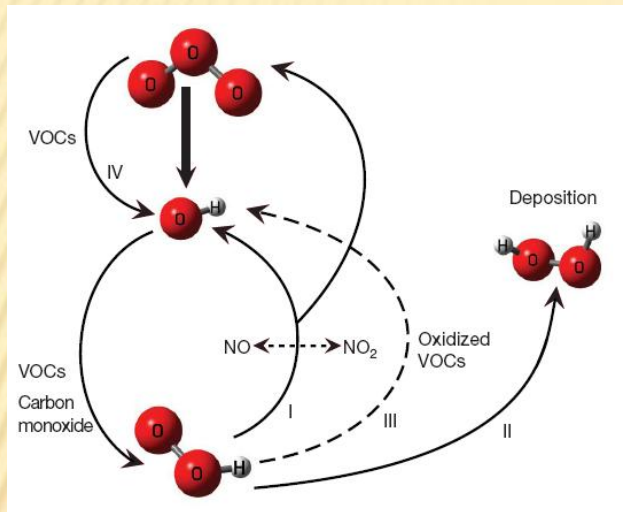
Bayesian Inversion: Emissions



	N America		S America	
	pri	proj	pri	proj
Biomass	0.8	2.8	4.0	5.4
Broadleaf	41.9	20.3	123	37.0
Shrub	13.5	10.7	29.6	21.5
OBVOC	0.2	0.2	2.5	6.3
Fossil	6.7	11.2	1.0	2.0
CH_4	38.9	38.9	40.4	40.4
Total	102	84.2	201	113

Much larger reduction of HCHO columns attributed to broadleaf than Shrub

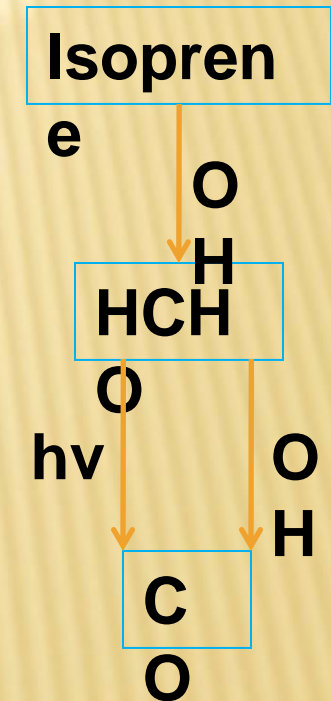
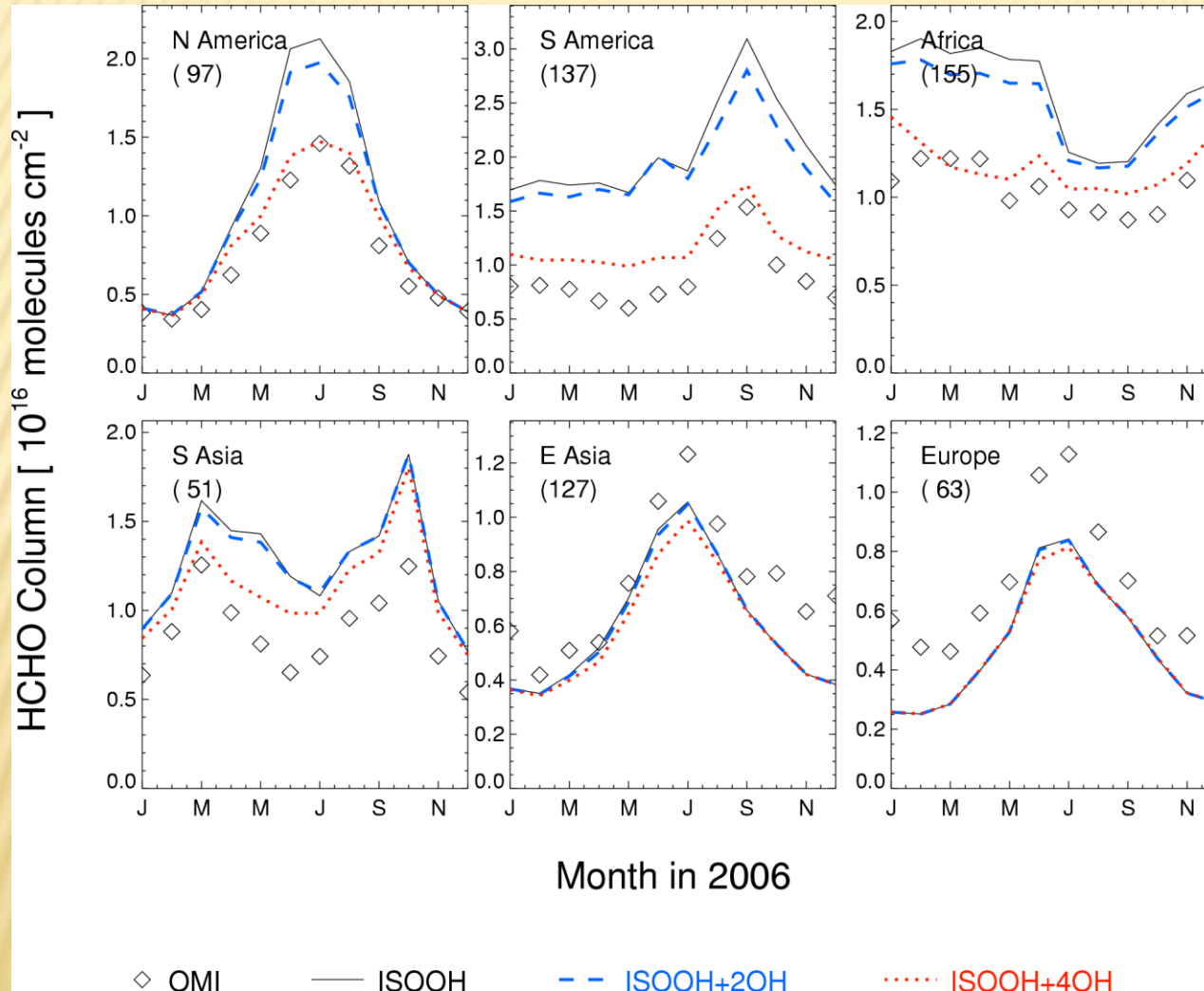
Recycling of OH in its oxidation of isoprene



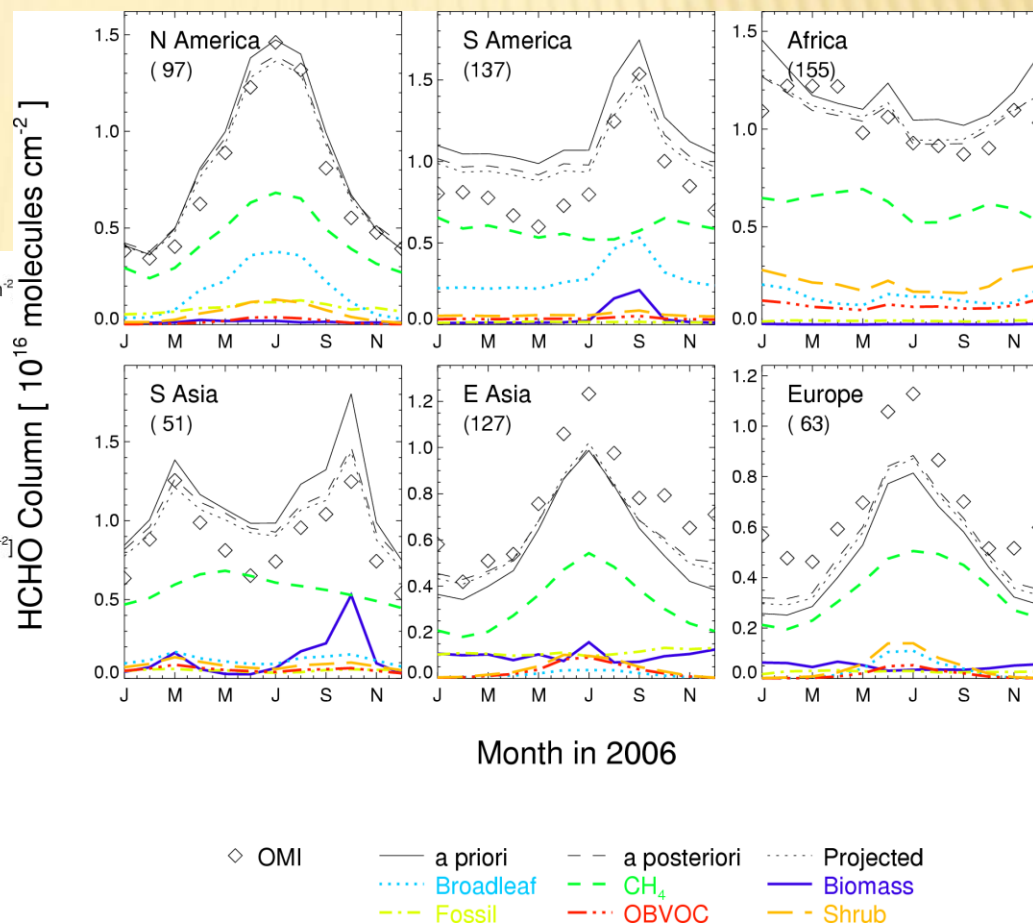
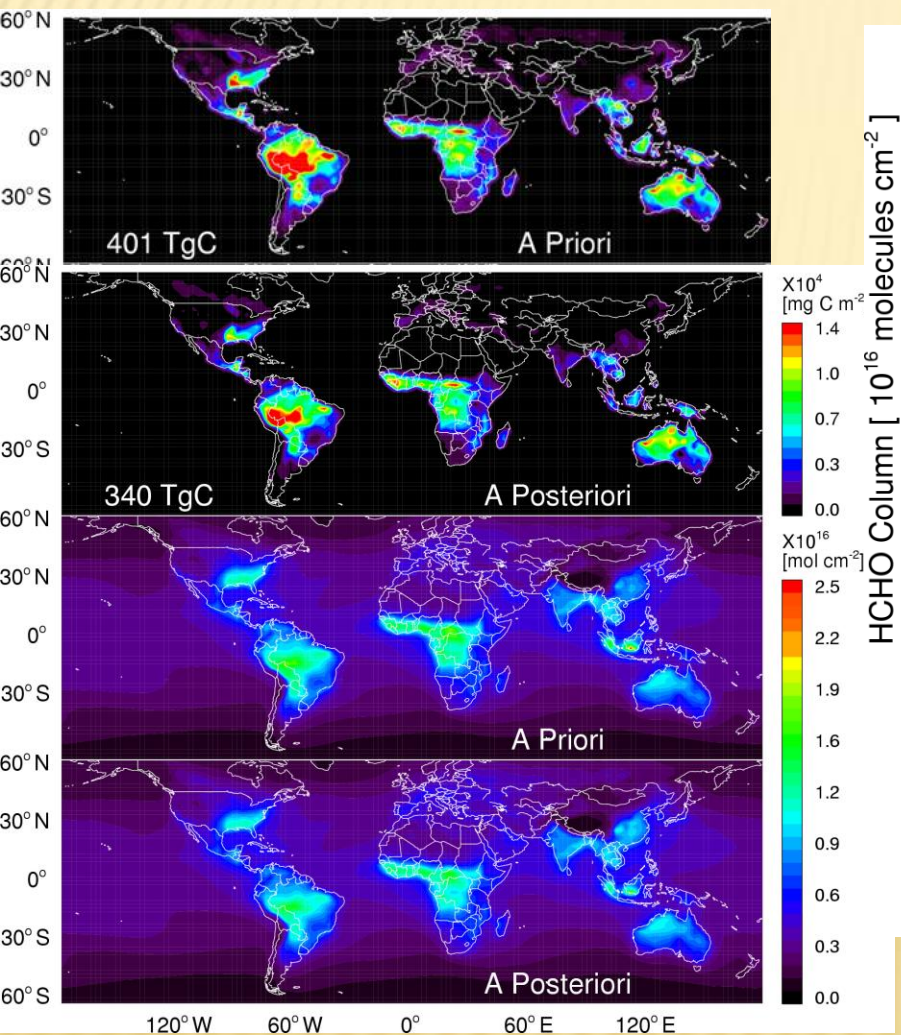
- Aircraft measurements in October 2005 between 3–6 N and 50–60 W over the tropical Atlantic Ocean and the pristine forests of Suriname, Guyana and Guyane (French Guiana)
- An OH recycling efficiency of 40–80% in isoprene oxidation is needed in modeling of observed OH. (Lelieveld et al., Nature, 2008)

- $\text{ISO}_2 + \text{HO}_2 \rightarrow \text{ISOOH} + n\text{OH}; n = 0, 2, 4$
The OH recycling efficiencies of 40 and 80% correspond to $n = 2$ and 4, respectively. (Butler et al., ACP, 2008)

Effects of OH recycling on inversion



Effects of OH recycling on inversion



Effects of OH recycling on inversion

Ratio of a posteriori to priori emissions

	N America		S America	
	Std	4OH	Std	4OH
Broadleaf	0.49	0.75	0.30	0.69
Shrub	0.79	0.85	0.69	0.68
OBVOC	0.99	1.84	2.57	1.67
Fossil	1.69	1.12	2.06	1.25
Biomass	3.36	1.66	1.36	0.93

A posteriori broadleaf emission reduction is much less

Recap

A priori:

401 Tg C yr⁻¹

A posteriori (no OH recycling):

266 Tg C yr⁻¹

A posteriori (OH recycling):

340 Tg C yr⁻¹

A posteriori regional uncertainty:

50-160%

Acknowledgements

- GEOS-Chem development and user community
- Funding support by the NASA Atmospheric Chemistry Modeling and Analysis Program